

**Noncontact proximity detector,  
especially for ferromagnetic components**

The invention relates to a noncontact proximity detector, especially for detection of ferromagnetic components, according to the preamble of claim 1.

In many technical applications, for example in mechanical engineering and the like, it is necessary to promptly and reliably detect the approach of one component to a second component using measurement technology. In the case of ferromagnetic components, Hall sensors are often used as proximity sensors or as sensors for noncontact determination of the state of components which change their position, in particular they can assume two different end positions. Hall sensors consist essentially of a semiconductor layer supplied with a constant current, usually in an integrated design. The constant current is influenced by a magnetic field component perpendicular to the semiconductor layer and the sensor delivers a Hall voltage which can be evaluated, which can be tapped and used to evaluate the state or also directly as an operating voltage. The integrated construction of Hall sensors makes it possible to integrate an evaluation circuit suitable for evaluating the operating state on the Hall sensor.

US-A-6,043,646 discloses a noncontact proximity detector for ferromagnetic components which can be used especially for motor vehicle applications. The proximity detector has a U-shaped permanent magnet with vertical magnetization which runs parallel to the U-legs. Between the U-legs a region free of magnetic flux is formed in which a magnetic field-sensitive sensor is mounted. When a flat ferromagnetic trigger part approaches the free poles of the U-legs parallel to the extension of the base of the U-shaped permanent magnet, the magnetic flux-free region between the U-legs is cancelled and the magnetic field-sensitive

sensor located there produces a signal which can be evaluated.

Building a proximity detector with a U-shaped permanent magnet and a magnetic field-sensitive sensor located between the U-legs requires very high precision. The U-legs which run on either side of the base of the U-shaped permanent magnet must be made as identically as possible and must be aligned as exactly parallel as possible so that a magnetic flux-free area is formed in the area enclosed by the U-shaped permanent magnet. Production of a special U-shaped permanent agent is inherently complex and expensive. The required accuracy of the U-shaped permanent magnet and the complex calibration of the magnetic field-sensitive sensors make the noncontact proximity detector even more expensive. For this reason, these components are used only for special applications in which costs play a subordinate role.

The object of this invention is therefore to devise a noncontact proximity detector with a simple structure. It is to be easily and economically producible. In particular the proximity detector is to be producible from simple standard components.

These objects are achieved in a noncontact proximity detector, especially for detecting the approach of ferromagnetic components, which has the features cited in the characterizing section of claim 1. Developments and/or advantageous versions of the invention are the subject matter of the dependent claims.

The noncontact proximity detector as claimed in the invention, especially for detection of the approach of a ferromagnetic component has at least one magnet arrangement which produces a magnetic flux and a magnetic field-sensitive sensor located in the action area of the magnetic flux. The magnetic field-sensitive sensor is a Hall sensor with at least one flat Hall measurement field. The vector of the magnetic flux within the magnet arrangement runs parallel to the two-dimensional extension of the Hall measurement field.

The proximity detector as claimed in the invention has a very simple structure of at least

one conventional magnet and a Hall sensor with at least one Hall measurement field. The sole condition is that the orientation of the magnetic field formed by the magnet within the magnet runs parallel to the two-dimensional extension of the Hall measurement field. In other words, this means that the direction of the magnetic flux of the bias magnet runs perpendicular to the direction of the measurement quantity determined on the Hall measurement field. With the approach of a ferromagnetic component the magnetic field of the bias magnet is distorted and the magnitude of the measured quantity tapped on the Hall measurement field changes. The tapped measured quantity can be further processed or after possible amplification can be used directly to trigger a switching pulse. The components used for the proximity detector are standard components which can be produced and assembled easily and economically. Due to its simple and economical structure the proximity detector can be used in a versatile manner wherever a change in the position of a ferromagnetic component is to be detected.

Advantageously the Hall sensor and the magnet arrangement are arranged such that they can be moved relative to one another at least in one direction which runs perpendicular to the direction of the vector of the magnetic flux. The relative mobility of the individual components facilitates adjustment and calibration of the proximity detector.

The proximity detector as claimed in the invention in its simplest embodiment comprises only a single magnet and a Hall sensor with at least one Hall measurement field. Another embodiment of the proximity detector comprises two magnets which are located at a distance from one another, with the magnetic fluxes which run within the magnets being directed parallel and preferably opposite one another. The Hall sensor is located in a neutral area which is made in the intermediate space between the two magnets. This neutral area is not a completely magnetic field-free region, rather the action of the magnetic fluxes in this zone is cancelled. The two bias magnets improve the sensitivity of the proximity detector without

unduly increasing the complexity of the system.

Other embodiments of the proximity detector as claimed in the invention can also comprise three or more magnets which are each arranged such that their magnetic fluxes run within the magnets parallel to the two-dimensional extension of the Hall measurement field. In the case of two or more bias magnets for the Hall sensor the magnets are arranged such that the vectors of the magnetic fluxes of at least two magnets which are opposite one another are pointed against one another. In this way a zone can be prepared in which the effects of the magnetic fluxes in one coordinate direction are cancelled. For three or more bias magnets they are advantageously arranged and oriented such that the vectors of the magnetic fluxes of all magnets point in the direction of the Hall sensors or in the opposite direction. For example, in the case of four magnets the magnetic fluxes run in pairs crossing one another. Due to the simultaneous alignment of the magnetic fluxes in the direction of the Hall sensor or away from it the action-free zone in which the Hall sensor is located can be defined very easily. Relative movability of the magnets to one another facilitates the exact alignment of the magnetic fluxes to one another.

The magnet arrangement can be formed for example by one or by several electromagnets which can be activated if necessary. In one feasible embodiment the magnet arrangement however comprises at least one bar-shaped permanent magnet. This has the advantage that a separate energy source is necessary and the proximity detector is practically permanently in readiness.

To reduce sensitivity to magnetic or electromagnetic interference fields, the Hall sensor can be made as a differential Hall sensor. The differential Hall sensor has at least two Hall measurement fields which are located next to one another or in succession relative to the direction of the vector of the magnetic flux. The magnetic field differences can be measured

with the sensor by the magnetic field-sensitive sensor's being made as a differential Hall sensor with two measurement fields. In finding the difference of the signals delivered from the Hall measurement fields, the interference influences of external magnetic fields do not apply. Due to the extensive insensitivity of the difference Hall sensor to external interference magnetic fields, smaller changes of the magnetic field which is applied to the difference Hall sensor can also be detected. The linear arrangement of the Hall measurement fields in succession or next to one another takes into account the circumstance that the motion of the components which change position takes place essentially linearly. In this way the prerequisites for optimization of the size of the signal change at the output of the difference Hall sensor are formed. Due to the use of a differential Hall sensor the arrangement of the magnetic field-sensitive sensor is relatively noncritical as long as it is located in the action area of the magnetic flux of the magnet. Generally complex adjustment of its relative position to the magnet can be abandoned. Effects by mechanical stresses, especially by vibrations, can be very easily compensated due to difference finding between the signals delivered by the Hall measurement fields.

It is also advantageous if the proximity detector comprises a Hall sensor with characteristics such as for example the application point, operating threshold, transconductance, etc., which can be subsequently tuned, especially programmed. Subsequent tuning can consist for example in the diodes on the Hall sensor being activated or deactivated or the resistance intervals being changed subsequently, for example with a laser, etc. Programmable Hall sensors have a control unit, for example in the form of an EPROMS or EEPROMS, which makes it possible to adapt and change the desired characteristics as desired. In this way the application range of the proximity detector can be adapted specifically to requirements.

Other advantages and features of the invention will become apparent from the following description of exemplary embodiments of the proximity detector as claimed in the invention for

detecting the approach of ferromagnetic components. The figures are schematic.

Figure 1 shows a first exemplary embodiment of a proximity detector as claimed in the invention with a magnet and a Hall sensor;

Figure 2 shows a second exemplary embodiment of the proximity detector with a Hall sensor located between the two magnets;

Figure 3 shows a version of the proximity detector as shown in Figure 1; and

Figure 4 shows another exemplary embodiment of the proximity detector as claimed in the invention.

The embodiment of the proximity detector 10 shown schematically in Figure 1 comprises a magnet 11 and a magnetic field-sensitive sensor 15 which is located in the action area of the magnetic flux J of the magnet 11. The magnetic field-sensitive sensor 15 is especially a Hall sensor with a flat Hall measurement field 16. The magnet 11 is made as a bar magnet; N and S label the magnetic north pole and magnetic south pole respectively of the ring magnet. The bar magnet 11 is arranged such that the magnetic flux J within the magnet 11 runs parallel to the surface of the Hall measurement field 16 of the Hall sensor 15. When the ferromagnetic component 3 which is indicated in the figure by the double arrow P approaches, the magnetic flux J is changed more or less dramatically. The change of the magnetic flux J as a result of the approach of the component 3 is detected. Depending on the base setting of the Hall sensor 15, for example, when a threshold value is reached, an electromagnetic signal is produced which is tapped on the Hall measurement field 16 and can be used for example for initiating a switching process. Advantageously the Hall sensor 25 and its bias magnet 21 are arranged to be able to move relative to one another.

The embodiment of the proximity detector 20 shown in Figure 2 comprises a Hall sensor 25 with a Hall measurement field 26 which is located between two bar magnets 21, 22

which are located at a distance from one another. The bar magnets 21, 22 are aligned with their north and south poles N and S such that their magnetic fluxes within the magnets 21 and 22 run parallel to the surface of the Hall measurement field 26 of the Hall sensor 25, but oppositely. This yields a zone between the two magnets 21, 22 in which the action of the magnetic fluxes of the two magnets 21, 22 is cancelled. The Hall sensor 25 is advantageously located between the two magnets 21, 22 such that the Hall measurement field 26 is located in the area of the flux-free zone. In this way the greatest possible sensitivity of the Hall sensor 25 relative to flux changes can be achieved. To facilitate the alignment of the magnets 21, 22 and the positioning of the Hall sensor 25 the components of the proximity detector 20 are advantageously arranged to be adjustable relative to one another. When the ferromagnetic component 3 approaches, the magnetic flux J is distorted and the flux-free zone in which the Hall measurement field is located is cancelled. The change of the magnetic flux is detected by the Hall sensor 25 and converted into electrical signals which are further processed. The magnetic fluxes J of the two magnets 21, 22 are pointed at the Hall sensor 25 in Figure 2. It goes without saying that the magnets 21, 22 can be arranged such that the magnetic fluxes in the Hall sensor 25 run pointed away.

The embodiment of the proximity detector 30 schematically shown in Figure 3 largely corresponds in terms of structure to the embodiment from Figure 1. The proximity detector comprises a magnet 31 and a magnetic field-sensitive sensor 35 which is located in the action area of the magnetic flux J of the magnet 31. The magnetic field-sensitive sensor 35 in this embodiment is a differential Hall sensor which has at least two flat Hall measurement fields 36, 37. The magnet 31 is made in turn as a bar magnet. N and S label the magnetic north pole and magnetic south pole respectively of the ring magnet. The bar magnet 31 is arranged such that the magnetic flux J within the magnet 31 runs parallel to the surface of the two Hall

measurement fields 36 and 37 of the Hall sensor 35. The relative movability of the bias magnet 31 and of the Hall sensor 35 to one another facilitates the alignment of the components. When the ferromagnetic component 3 which is indicated in turn in the figure by the double arrow P approaches, the magnetic flux J is changed more or less dramatically. The two Hall measurement fields 36, 37 detect the locally different flux change. The resulting electromagnetic signals are used to find the difference. In this way the effects of interference of external electromagnetic stray or interference fields can be eliminated. The electrical difference signals delivered by the differential Hall sensor 35 are a direct measurement of the change in the position of the ferromagnetic component 3 and can be further processed or used for direct switching processes or the like.

The embodiment of the proximity detector as claimed in the invention which is shown in Figure 4 is provided altogether with reference number 40. It comprises four magnets 41, 42, 43, 44 which are made for example as bar-shaped permanent magnets and are mounted to be able to move relative to one another. The bar magnets 41-44 are arranged in a square and surround an area in which a Hall sensor 45 with a flat Hall measurement field 46 is located. The position of the Hall sensor 45 relative to the bar magnets 41-44 can be changed. The alignment of the bias magnets 41-44 for the Hall sensor 45 is such that the direction of the magnetic flux J within the magnets 41-44 runs parallel to the surface of the flat Hall measurement field 46 of the Hall sensor 45. The north and south poles N and S of the magnets 41, 42 and 43, 44 which are opposite one another are oriented such that the magnetic fluxes J of a magnet pair 41, 42 and 43, 44 run parallel, but opposite one another. In the illustrated embodiment the magnets 41-44 are oriented such that the magnetic fluxes J run in pairs perpendicular to one another. In particular, in the illustrated exemplary embodiment the direction of all magnetic fluxes J are oriented away from the Hall sensor 45. It goes without saying that the direction of the magnetic fluxes can also



run in reverse. The orientation of the magnets can also be selected such that the directions of the magnetic fluxes of a pair of magnets opposite one another point toward the Hall sensor, while the magnetic fluxes of the second pair of magnets point away from the Hall sensor. When a ferromagnetic component 3 which is indicated by the double arrow P approaches, the magnetic flux in the area surrounded by the bias magnets 41-44 is changed and detected by the Hall sensor. The resulting magnetic measured quantities are tapped and further processed.

To suppress the effects of magnetic stray and interference fields, instead of a Hall sensor a differential Hall sensor with at least two Hall measurement fields can be used. It can also be advantageous if the proximity detector comprises a Hall sensor with characteristics such as for example the application point, operating threshold, transconductance, etc., which can be subsequently tuned, especially programmed. Subsequent tuning can consist for example in the Hall sensor having diodes which can be subsequently activated or deactivated in order to change its characteristics. The Hall sensor can also be equipped with resistance intervals which if necessary can be subsequently changed for example with a laser. Programmable Hall sensors have a control unit, for example in the form of an EPROMS or EEPROMS, which makes it possible to adapt and change the desired characteristics as wished. In this way the application area of the proximity detector can be adapted specifically to requirements.

It goes without saying that the component 3 shown in Figures 1-4, the approach of which is to be ascertained by a proximity detector, need not consist entirely of a ferromagnetic material. It can be a component of other materials which is connected to the ferromagnetic part or which surrounds it, etc. The described proximity detector can be used wherever the approach of a component which has a ferromagnetic component is detected and used to trigger other processes, for example switching processes. One application consists for example in detection of the closing of a belt lock in motor vehicles, which as an indicator for activation or

deactivation of mechanisms for inflating driver and passenger airbags or side airbags [sic].